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(54) A phase shifter panel for an electronic scanning antenna

(57) A phase-shifter panel with four phase states, includes conducting wires (F) arranged parallel to the direction of the electric field of an incident wave on a dielectric support (1); each wire bears at least two diodes (D_1 , D_2) mounted in opposition and supplied via control conductors (51, 52, 53) which enable the state of the diodes to be controlled independently of one another. The geometrical and electrical characteristics of the panel are such that to each of the states of the diodes corresponds a given value of phase shift. Conductors (74, 75) parallel to the control conductors are arranged towards the periphery of the support (1).

A stack of such panels forms an active microwave lens for an electronic scanning antenna.

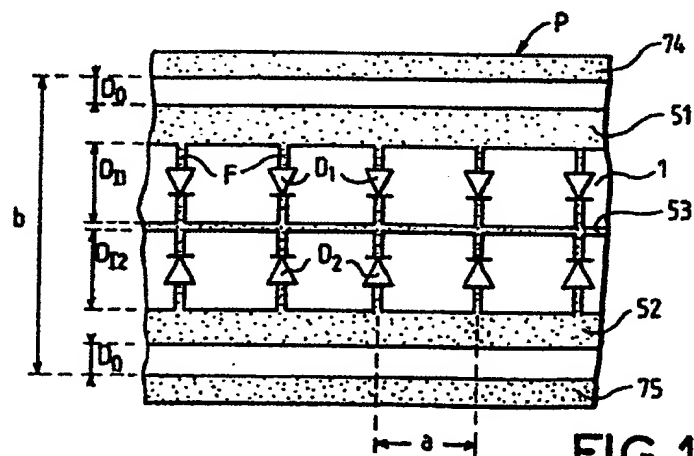


FIG.1

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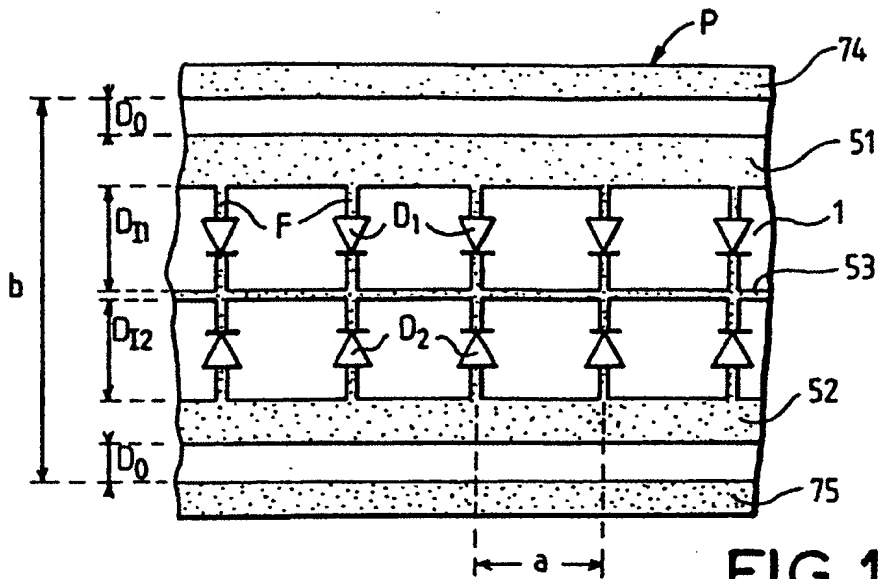


FIG.1

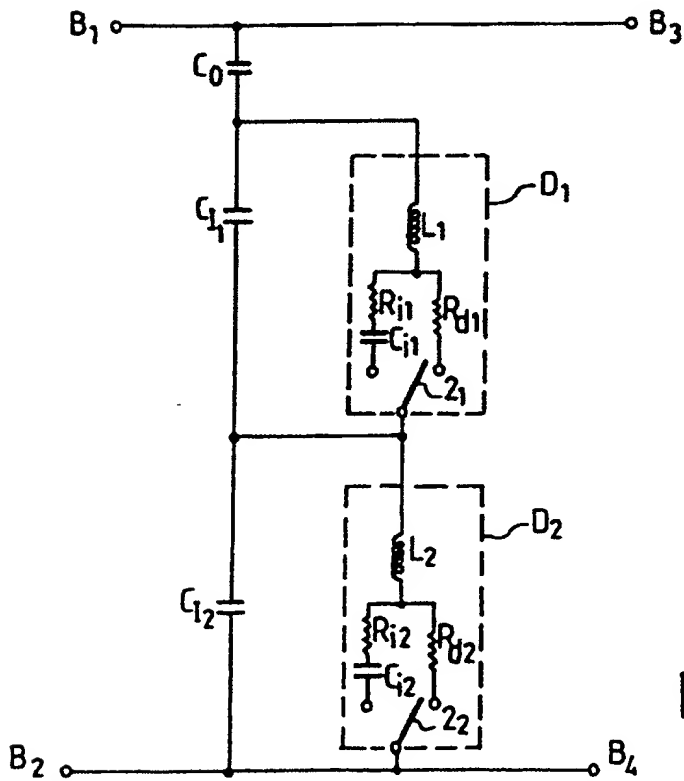
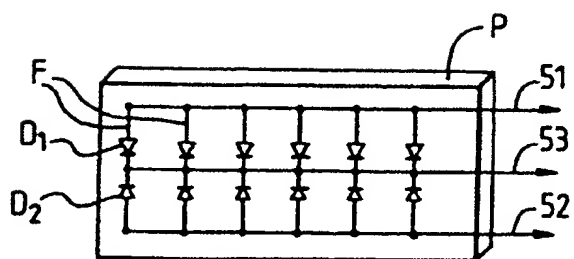
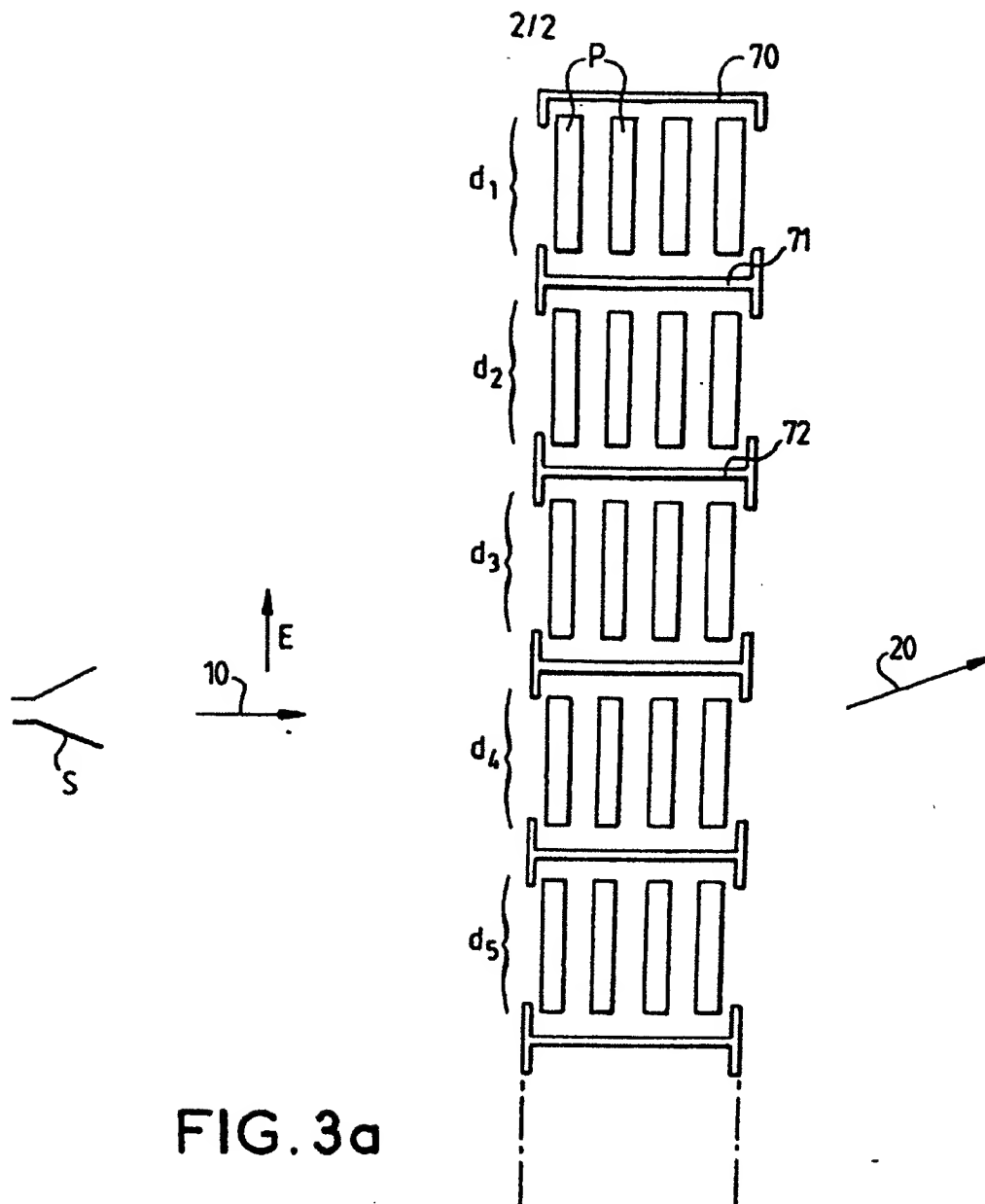


FIG.2



"A PHASE SHIFTER PANEL
AND ITS APPLICATION TO A MICROWAVE LENS
AND TO AN ELECTRONIC SCANNING ANTENNA "

The present invention relates to a phase-shifter
5 panel with four phase states, using active semiconductor
elements. Its subject is also the application of such a
panel to the construction of a microwave lens and an
electronic-scanning antenna.

The construction of an electronic-scanning
10 antenna requires, as is known, components capable of
applying a controllable phase shift to a microwave. It is
known for example from French Patent 2,469,808 to use, in
order to construct an electronic-scanning antenna, a microwave
lens formed from panels each introducing a phase shift of
15 the microwave which passes through them. These panels
include conducting wires bearing diodes, the wires being
arranged parallel to the direction of the electric field
of the wave. Control of the passing or blocked state of
the diodes enables the phase shift imparted to the
20 incident wave by each of the panels to be made to vary
between two values and, consequently, electronic scanning
to be obtained.

However, such an antenna requires that the larger
the desired number of distinct values of phase shift, the
25 larger the number of phase-shifter panels, arranged in
the path of the wave, with an increase in the losses and
in the cost in particular, this constituting a limita-
tion.

The subject of the present invention is a phase-
30 shifter panel which makes it possible to obtain four
distinct values of phase shift depending on the command
applied thereto, and thus making it possible in parti-
cular to reduce the number of panels required in the
above application.

35 According to the invention there is provided
a phase-shifter panel capable of receiving an electro-
magnetic wave linearly polarized in a given direction;
the panel includes conducting wires arranged on a

support, the wires each bearing at least two semiconductor elements, diodes for example, and being connected to conductors enabling the state of the diodes to be controlled independently of one another, each of the diodes
5 being able to be in the passing or blocked state; four possible states are thus obtained, and the geometrical and electrical characteristics of the panel are such that to each of these states corresponds a given value of phase shift.

10 The subject of the invention is also the application of such a panel to the construction of a microwave lens of the type described in the aforesaid patent.

Its subject is also the use of such a lens for the construction of an electronic-scanning antenna.

15 Other subjects, features and results of the invention will emerge from the following description given by way of example and illustrated by the appended drawings which represent:

- Figure 1, a diagram of an embodiment of a panel
20 according to the invention;

- Figure 2, the equivalent electrical circuit diagram of the panel of the preceding figure;

- Figures 3a and 3b, diagrams illustrating the microwave lens which is the subject of the aforesaid French
25 patent and its application to the construction of an electronic-scanning antenna.

In these various figures, the same references refer to the same elements.

In Figure 1 is represented a partial view of one
30 embodiment of a panel according to the invention.

This panel is labelled P overall. It includes a dielectric substrate 1 on which are arranged wires F, substantially parallel to one another and each carrying at least two semiconductor elements with two states, D₁
35 and D₂, for example diodes, for example connected in opposition, for example by their cathode. The supply voltage to the diodes D₁ and D₂ is conveyed by three conductors which are substantially parallel to one another and perpendicular to the wires F, labelled 51, 52

and 53, the conductor 53 being the central conductor. The substrate 4 furthermore includes on its two edges, respectively, two metal conductors labelled 74 and 75, substantially parallel to the conductors 51-53 and arranged at a distance D_0 on either side respectively of the conductors 51 and 52. The conductors 51 and 53 are a length D_{11} apart and the conductors 53 and 52 a distance D_{12} apart. The wires F are substantially equidistant, with a spacing a . The conductors 74 and 75 are a length b apart.

For the clarity of the figures, the surface of the various conductors, made for example in the form of metallic depositions on the substrate 4, is represented in the figure dotted although not seen in section.

Figure 2 represents the equivalent electrical diagram of the panel of Figure 1, for microwaves.

The microwave, with impedance $Z = 120.\pi.b/a$ and linearly polarized (electric field vector) parallel to the wires F is received on the terminals B_1 and B_2 and encounters three capacitances C_0 , C_{11} , C_{12} in series, connected in parallel across the terminals B_1 and B_2 . The capacitance C_0 represents the decoupling capacitance per unit length between the conductors 51 and 52 and the conductors 74 and 75, respectively; the capacitance C_{11} is the capacitance per unit length between the conductors 51 and 53 and the capacitance C_{12} the capacitance per unit length between the conductors 53 and 52.

Across the terminals of the capacitance C_{11} is connected a diode D_1 , also represented by its equivalent diagram. The latter consists of an inductor L_1 in series with:

- either a capacitor C_{11} in series with a resistor R_{11} ,

- or a resistor R_{d1} ,

depending on whether the diode D_1 is reverse or forward, this being depicted by a switch 2_1 .

Likewise, across the terminals of the capacitor C_{12} is connected a diode D_2 represented by its equivalent diagram. The latter is analogous to that for the diode

D_1 , its components bearing an index 2.

The microwave output voltage is taken between the terminals B_3 and B_4 , the terminals of the three capacitors C_0 , C_{11} and C_{12} .

5 The parameters of the equivalent circuit of the diodes, for example of diode D_1 , are defined as follows:

- the inductance L_1 is given by $L_1 = L_{D1} \cdot \frac{a^\alpha}{b}$,

where: L_{D1} is the inductance of the diode D_1 , bearing in mind its connection wire (F) to the conductors 51-53; a is the distance between two diodes D_1 ; b is the distance between the conductors 74 and 75; α is a coefficient characterizing the interaction between the wires F;

- the resistance R_{11} is the reverse resistance of the diode D_1 , modified by the ratio a/b ;

15 - the resistance R_{d1} is the forward resistance of the diode, modified by the same ratio;

- the capacitance C_{11} is the junction capacitance of the diode, modified by the ratio b/a .

20 The operation of the panel according to the invention is explained below by considering, in a first step, the behaviour of such a panel in the absence of the diodes D_2 and of the conductor 53, which amounts to deleting the block D_2 as well as the capacitor C_{12} from the equivalent diagram of Figure 2.

25 When the diodes D_1 are forward biased, the susceptance (B_d) of the (altered) circuit of Figure 2, can be written:

$$B_d = Z \cdot C_0 \cdot \omega \cdot \frac{1 - LC_1 \omega^2}{LC_1 \omega^2 + LC_0 \omega^2 - 1}$$

30 where ω is the angular frequency corresponding to the central frequency of the operating band of the device.

The parameters of the circuit are chosen so as to have $B_d \approx 0$, that is to say that, neglecting its conductance, the circuit is matched or, in other words, that it is transparent to the incident microwave, introducing
35 neither spurious reflection nor phase shift ($d\phi_{d1} = 0$).

More precisely, we choose:

$$LC_1 \omega^2 = 1$$

which leads to $B_d \approx 0$, irrespective in particular of the value of the capacitance C_{11} .

5 When the diodes are reverse biased, the susceptance of the panel can be written:

$$B_R = Z \cdot C_o \cdot \omega \frac{1 - LC_1 \omega^2 + (C_1 / C_i)}{LC_1 \omega^2 + LC_o \omega^2 - 1 + (C_o + C_1) / C_i}$$

10 With the capacitance C_1 being fixed previously, it appears that the value of the susceptance B_R can be adjusted as, consequently, can that of the phase shift ($d\phi_{11}$) experienced by the incident microwave, through action on the value of the capacitance C_i , that is to say through the choice of the diode D_1 .

15 Two values of phase shift are thus obtained: $d\phi_{11} = 0$ and $d\phi_{11}$.

If now, in a second step, the existence of the diodes D_2 and of the intermediate conductor 53 are taken into consideration, it is seen that, by an analogous argument, when the diode D_2 is forward biased, the incident microwave experiences no phase shift ($d\phi_{22} = 0$) whereas when the diodes D_2 are reverse biased, it experiences a given and adjustable phase shift ($d\phi_{12}$).

25 If now the whole of the panel is considered, it is seen that it can impress upon the microwave which passes through it four different values of phase shift, depending on the control (forward or reverse bias) applied to each of the diodes D_1 and D_2 .

Indeed:

30 - when the diodes D_1 and D_2 are forward biased, the phase shift ($d\phi_1$) imparted to the incident wave is zero;

- when the diodes D_1 are forward biased whilst the diodes D_2 are reverse biased, the phase shift introduced ($d\phi_2$) is so by the diodes D_2 alone and is therefore dependent on the value of the capacitance C_{12} ;

- conversely, when the diodes D_1 are reverse biased whilst the diodes D_2 are forward biased, the phase shift ($d\phi_1$) imparted by the panel is so by the diodes D_1 alone and is therefore dependent on the capacitance C_{11} of these diodes;

- when, together, the diodes D_1 and D_2 are reverse biased, the phase shift ($d\phi_1$) is due at once to the diodes D_1 and D_2 and is therefore dependent on C_{11} and C_{12} .

It should be noted that described above is the case in which the parameters of the circuit are chosen so that the zero (or substantially zero) susceptances are such that they correspond to the diodes biased in the forward direction, but that it is of course possible to choose a symmetric operation in which the parameters are determined so as substantially to zero the susceptance B_2 .

Such a panel can advantageously be used in the construction of a microwave lens of the type described in the aforesaid patent and shown diagrammatically in Figures 3a and 3b:

- Figure 3a is a partial and diagrammatic sectional view in the plane of the electric field E of the microwave;

- Figure 3b illustrates the structure of a panel such as described earlier.

In Figure 3b is the panel P bearing the wires F , each of them bearing a diode D_1 and a diode D_2 which are connected by their cathodes for example, as well as the conductors 51, 52 and 53.

The microwave lens of Figure 3a includes a plurality of panels such as P , arranged between conducting plates 70, 71, 72, which play the role of the conductors 74 and 75 of Figure 1. Together, the panels P arranged between two plates 70-72 constitute a phase shifter (d_1, d_2, d_3, \dots).

The stack of a plurality of phase shifters constitutes an active microwave lens which, when irradiated by a microwave source S , makes it possible to form an electronic scanning antenna. The source S provides an electromagnetic wave whose direction of propagation is

illustrated by an arrow 10 and whose electric field E is perpendicular to the plates 70, 71, 72... and parallel to the wires P bearing the diodes.

5 With the panels P being controlled independently of each other, it appears that the phase shifts which they impart to the wave which passes through them can differ from one panel to another. By juxtaposing a plurality of panels one behind the other in the path of the microwave, it is seen that phase shifts can be
10 obtained which can range from 0 to 360° , in increments linked to the number of juxtaposed panels. It should be noted that the fact that each of the panels according to the invention is able to impart to the wave which passes through it four different phase shifts makes it possible
15 to reduce the total number of panels. By stacking a plurality of such phase shifters, it appears that it is possible to effect electronic scanning in a plane parallel to the electric field, as illustrated by an arrow 20 showing the direction of propagation of the
20 emergent wave.

The description given above of the panel was so of course by way of example and different variants are possible: thus, it is possible to connect to a same wire several diodes such as D_1 in the same sense and/or
25 several diodes D_2 , also in the same sense; this variant makes it possible to decrease the equivalent capacitance of the setup and, consequently, to increase its passband. Similarly, the diodes D_1 and D_2 have been represented as connected in opposition but they can also be connected in
30 series, on condition that the control circuits are adapted accordingly. Finally, the conductor 53 can be doubled up, and this may ease the supplying of the diodes D_1 and D_2 .

CLAIMS:

1. A phase shifter panel capable of receiving an electromagnetic wave linearly polarized in a given direction, including a dielectric support and electrically conducting wires substantially parallel to the given direction, and arranged on the support, the wires being connected to conductors for control of the semiconductor elements, substantially normal to the wires; wherein the support furthermore includes two conductors arranged towards the periphery thereof, substantially parallel to the control conductors, and wherein the wires bear at least two semiconductor elements with two states, the control conductors being at least three in number so as to control the state of the semiconductor elements independently of one another, the geometrical and electrical characteristics of the panel being such that to each of the states of the semiconductor elements corresponds a given value of phase shift of the electromagnetic wave which passes through it.

2. A panel according to claim 1, wherein the semiconductor elements are diodes.

25

3. A panel according to either claim 1 or claim 2, wherein the geometrical and electrical characteristics

of the panel are such that the latter is adapted for one of the states of the semiconductor elements.

4. A microwave lens capable of receiving a microwave,
5 including a plurality of phase shifters, each of them
being formed of a plurality of panels according to anyone
of the preceding claims, arranged substantially parallel
to one another between conducting plates, in the
direction of propagation of the microwave, the phase
10 shifters being stacked normal to the said direction.

5. An electronic scanning antenna, including a lens
according to claim 4 and a source which is capable of
emitting an electromagnetic wave linearly polarised in
15 said direction, the electronic scanning being obtained
in the plane of said direction by control of the state
of the semiconductor elements.

6. A phase shifter panel substantially as described
20 hereinbefore with reference to the accompanying drawing
and as illustrated in Figures 1 and 2 of those drawings.

7. A microwave lens capable of receiving a microwave
substantially as described hereinbefore with reference
25 to and as illustrated in the accompanying drawings.

8. An electronic scanning antenna substantially as

6

described hereinbefore with reference to and as
illustrated in the accompanying drawings.

Patents Act 1977
Examiner's report to the Comptroller under Section 17
(The Search report)

Application number
 GB 9415853.2

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Relevant Technical Fields

(i) UK Cl (Ed.M) H1Q (QEE, QEX, QFF, QFH, QFJ, QFX)

(ii) Int Cl (Ed.5) H01Q 3/46

Search Examiner
 J E EVANS

Date of completion of Search
 8 NOVEMBER 1994

Databases (see below)

(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii)

Documents considered relevant following a search in respect of Claims :-
 1-8

Categories of documents

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|--|---|

Category	Identity of document and relevant passages	Relevant to claim(s)
P A	EP 0595726 A1 (THOMSON-CSF) - 4 May 1994 - see abstract	1-8
A	US 4447815 (CHEKROUN) - see Figures 4 and 5	1-8

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